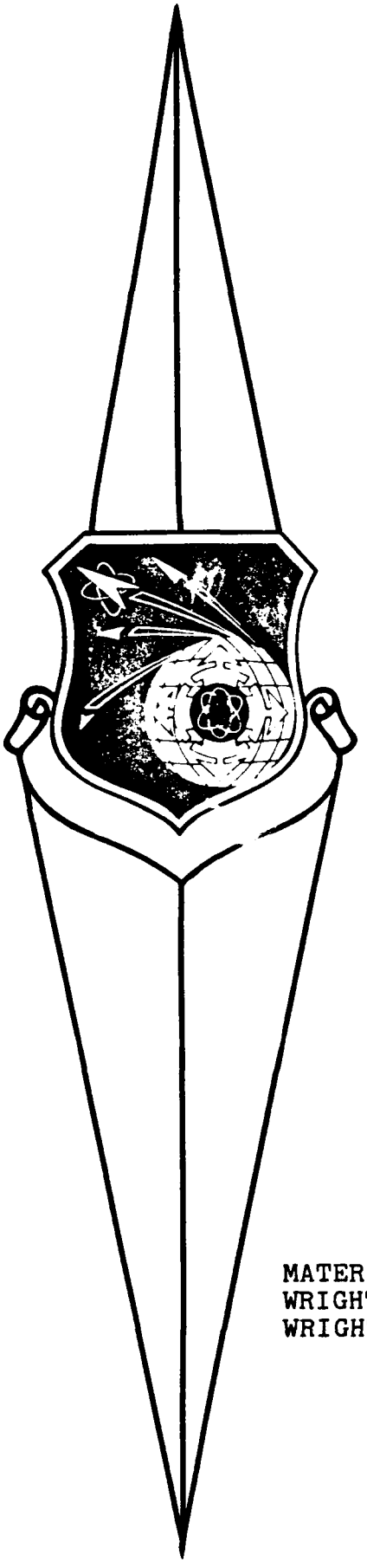

TECHNICAL MEMORANDUM
WRDC-TM-90-400 (MLS)

COMPUTERIZATION OF MIL-HDBK-5: SUGGESTIONS, GUIDELINES, AND RELATED EFFORTS.

MATERIALS ENGINEERING BRANCH
SYSTEMS SUPPORT DIVISION

TECHNICAL MEMORANDUM TM-90-400 (MLS)

JULY 1990

MATERIALS LABORATORY
WRIGHT RESEARCH AND DEVELOPMENT CENTER
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This report has been reviewed and is approved for publication.

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FOREWORD

This report describes work performed from 9-20 July 1990 for a two-week active duty reserve tour by US Air Force Reserve Captain Torsten M. Rhode.

The author wishes to thank Mr. Clayton Harmsworth for his direction and assistance in this effort.

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I. INTRODUCTION:

The computerization of MIL-HDBK-5 has been a goal of the MIL-HDBK-5 Coordination Group for several years. Several programs have been initiated by public and private organizations to try to include some MIL-HDBK-5 design allowables in computerized databases. However, there has been no disciplined, integrated approach to computerizing the entire handbook as a true digital representation of the printed document.

By DOD and FAA regulation, MIL-HDBK-5 is the definitive source of design allowables for metallic structural materials for use in aircraft; it also defines the procedures for developing allowables for materials not in the handbook. Therefore, "computerizing" MIL-HDBK-5 does not imply simple keypunch entry of allowables data into a computer database. By definition, any computerized version of MIL-HDBK-5 would require the same technical guidelines for use of the data, and the same graphical representations of data curves, that the current printed version contains.

This report will detail the objectives of computerizing MIL-HDBK-5 and address some of the concerns that users of a computerized version of the handbook may have. Two examples of computerized databases will be discussed. The first, a commercial venture under the management of the Materials Property Database

(MPD) Network, Inc., is associated with Chemical Abstracts Service. It is of interest because of its success in digitizing MIL-HDBK-5 materials property curves in a format usable by a designer. The other effort is called the Advanced Materials Database System (AMDBS) and is under development by PDA Engineering, Costa Mesa, California. AMDBS is notable in the fact that it incorporates a user-friendly interface with a powerful data search and display function. One unsuccessful effort will also be discussed, which was an attempt to construct a Spacecraft Materials Database by SRS Technologies, Huntsville, Alabama. This report will finally present a plan which will detail the specific actions that should be taken over the next 4-6 months to initiate development of a computerized version of MIL-HDBK-5.

II. APPROACHES TO MIL-HDBK-5 COMPUTERIZATION:

There are two different approaches envisioned for computerizing MIL-HDBK-5. The first would simplify publishing and updating the handbook; the second would develop an interactive, computerized database of MIL-HDBK-5 allowables. Each approach will be discussed independently.

A. APPROACH #1: PUBLISHING AND UPDATING: MIL-HDBK-5 is currently maintained and updated by Battelle Memorial Institute, Columbus, Ohio, under contract to the US Air Force Materials Laboratory at Wright-Patterson AFB, Ohio. A computerized version of MIL-HDBK-5 would be of great utility to these custodians of the document by storing the information digitally on computer media instead of as a hardcopy.

As the handbook is currently configured, an original master copy of the document is maintained. The master copy is composed of text, tables, and graphs. The text portion of the master copy is stored in a word processor file, while the tables are typewritten. Graphs are kept on file as hardcopy. None of the graphs or tables are stored in computer form by the custodian.

When the handbook is updated or changed, the updated sections (text, tables, illustrations, and graphs) are forwarded to the Naval Publications Center in Virginia for printing. The text

in the word processor file is edited and laid out in the proper format, and the tables, illustrations, and graphs are cut and pasted in place for photographing. The document is then printed. This process is awkward at best. It carries a high risk that the manuscript may be lost, or that transcription errors may be included in the final handbook. Also, there is a significant time lag between when changes are initiated and when the printed changes are mailed.

As described above, the current MIL-HDBK-5 is primarily a paper manuscript. Although the text is stored in word processor files, a significant amount of hand layout of text, tables, illustrations, and graphs is still required. Using available technology, more of the handbook can be stored on computer disk. For this application, a disk-based system is preferable to a network because only a few users directly associated with printing or updating the handbook would need access to it. An improved disk-based system could be constructed using immediately available technology:

Text and Tables. Many, if not most, desktop publishing programs allow the user to incorporate spreadsheets in a word-processed document. Therefore, a document can incorporate tables within text. The individual spreadsheet files can be saved independently, as well.

Graphs. A computerized version of the handbook designed solely for printing and updating does not need mathematical (or

true graphical) representations of graphs and curves. All that is required is the ability to reproduce the curve accurately on paper. Therefore, a high resolution scanned image of each graph is probably sufficient. The document custodian can then print hardcopies of graphs and forward them to the publications center. The computer in this case becomes simply an electronic filing cabinet.

Illustrations. Illustrations can be drawn on a CAD system and saved on disk for later plotting or printing. Again, the computer serves as an electronic file cabinet. However, changes or additions to a CAD file are fast and easy to make.

A procedure using the three elements above would probably meet the minimum requirements of a computerized MIL-HDBK-5 for ease in updating and printing. It would not be very user friendly, and it would be impossible in the form described above to leaf through pages of the handbook electronically and see graphs, text, and illustrations in the proper places. The benefit would be that even if the manuscript that was mailed to the publication center was lost, a new original of the document could be constructed fairly easily. In addition, updates would be fairly easy to make to all of the text or figures.

Constructing a Navy-Compatible Version: Mr. Mike Sadagursky of the Naval Publications Center was contacted to define the Navy's requirements for a "true" computerized version of the

handbook. In other words, Mike was asked what the Navy needs in order for the custodian to be able to mail a disk which contains each page of the handbook in exactly the format readable by the Navy's computers. Mike's comments were as follows:

1. The Naval Publications Center uses a publishing program which "marks up" a document to designate headings, footings, primary paragraphs, secondary paragraphs, and so on. The marked up document is then ready for printing in the proper format. Their program recognizes a computer language called the "Standard Generalized Markup Language" (SGML). SGML is described in MIL-S-28001. To send a document to the Publications Center in marked-up form (to avoid waiting for them to mark it up), Mike recommended input of the MIL-HDBK-5 text into a desktop publishing program designated to be "SGML Compatible."

2. All figures should be stored in a format called the "International Graphics Exchange Standard" (IGES). Most CAD systems can store a file in IGES, which is a format readable by many different software packages. It would be possible to recreate the MIL-HDBK-5 graphs and illustrations on a CAD system and store them in IGES. This would have the dual benefit of storing the graphs as true curves, rather than as pictures of curves.

The benefits of constructing a Navy-compatible MIL-HDBK-5 file is that all the layout, changes, and additions could be made

by the document custodian. Then, a handbook in ready-to-print form could be forwarded directly to the Naval Publications Center on disk. This should make the implementation of changes faster and more reliable.

Before any action to this end is taken, Mr. Sadagursky recommended that a series of meetings and discussions be made between all those who are responsible for reviewing, updating, and printing the document to further define the Navy requirements.

B. APPROACH #2: AN INTERACTIVE DATABASE: Another approach to computerizing MIL-HDBK-5 is to create a reference MIL-HDBK-5 database which could be used by designers and other engineers. This database would be a true electronic handbook. However, MIL-HDBK-5 is more than a tabulation of materials design allowables. The handbook contains footnotes, warnings, and cautionary statements which cannot be separated from individual allowables values. Without the footnotes or warnings, the allowables become subject to misinterpretation, misuse, and abuse. The footnotes ensure that the designer or engineer uses the allowable properly, subject to the limitations inherent in the material or the test method described. These notes and statements are the key to MIL-HDBK-5's significance as the DOD and FAA's standard handbook of metallic materials.

For this reason, the MIL-HDBK-5 Coordination Group has determined that any attempt to create a true computerized version of the handbook for use as a reference database must portray each page or section of the handbook exactly as it currently appears in printed form. For example, each footnote should be displayed at the same time as the data it describes. Each warning statement should be displayed on the screen with the data. There should be no chance that data with footnotes could be displayed without the notes on the screen.

Another requirement of a computerized MIL-HDBK-5 database is the need to depict true data plots for graphical data, and not just "pictures of graphs." For example, the designer often interpolates data from a printed curve in the current hardcopy version of the handbook. A computerized version would ideally display a curve in such a manner that a designer could point to a part of the curve with a mouse and let the computer display the appropriate x-y coordinates. This would require a true graphical representation of the curve and not a saved "snapshot:" in most cases, a computer can not recognize x-y coordinates of points in a "snapshot" image. The mechanics of saving a true graph vs. a "snapshot" are substantially different and more complex.

Another concern of many MIL-HDBK-5 users is in defining the objective of the computerization. Is the handbook to be computerized to develop a means of automatically optimizing materials selection? Is the purpose to develop an expert system to assist in design? The development of a universal expert design optimi-

zation system is beyond the scope of any MIL-HDBK-5 computerization effort. The purpose of the handbook is to describe the mechanical properties of aerospace materials. The responsibility of the custodian is to ensure that those properties are accurate, and that appropriate warnings and cautions are included with the data. The handbook should also describe guidelines for data presentation, and data requirements, just like the printed handbook does today. The computerized MIL-HDBK-5 database should meet those objectives alone, and leave the development of design optimization systems to others.

In short, a computerized MIL-HDBK-5 database must be a true duplication of the printed handbook. The graphs must be able to be used as true x-y plots, allowing the designer to select a point on the curve to get the actual x-y coordinates. The warnings should be "attached" to the data. The text should be included in detail, exactly as it appears in the current printed form.

III. PC-BASED VS. NETWORK SYSTEM:

The two approaches outlined above could lead to two different formats for the MIL-HDBK-5 database. The "publishing" version of the handbook is best suited to a PC-based disk or tape version. This would allow easy shipment for publishing, and it would allow careful control of the disks so that the prospect of a random proliferation of updated and non-updated versions is avoided. The computerized MIL-HDBK-5 reference database is best suited to be a network version. This would allow very rapid, system-wide updates with a minimum of effort.

A. The PC-Based System: Since an "publishing" computerized version is not specifically intended for general consumption, control of the disks is a fairly simple affair. A version of MIL-HDBK-5 computerized solely for publication and updating purposes should not be distributed beyond a few, select users involved in updating or printing the handbook. The disks can be copy-protected to prevent uncontrolled distribution, and a control list of recipients can be maintained to ensure that the copies are updated periodically to all disk holders. Safeguards can be incorporated to notify users of the handbook version number or the "expiration date" of the disks. For example, a fixed, semi-annual revision cycle of the handbook can be mandated in which new disks are mailed to all users on the control list. Each "page" displayed on the screen from the disks can have a message shown on the bottom of the screen which would say, "MIL-

HDBK-5G, CHANGE NOTICE 3. DO NOT USE AFTER JULY 1, 1994." Even if no changes were made, new disks are inexpensive and they could be mailed to all users on the control list semi-annually. The new disks would be annotated with new "expiration" dates.

B. A Network System: MIL-HDBK-5 as a reference, user-oriented database is best suited for a network. In this way, the custodians of the document can be sure that only the most recent, updated version is in general use.

Many aircraft manufacturers use in-house databases for design of aircraft. These databases include MIL-HDBK-5 design allowables which are manually entered into the computers. Aircraft designers are also responsible for keeping historical records of design allowables used at the time the aircraft was certified. Therefore, the database should be down-loadable, and the down-loaded MIL-HDBK-5 should be allowed to be printed.

The primary feature of a computerized, networked handbook is that changing the handbook becomes a simple matter. New values are entered, users are notified, and the changes become legal requirements. This efficiency may not be realized, however. The function of the MIL-HDBK-5 Coordination group is to discuss the merits and validity of proposed revisions, additions, or changes, and recommend acceptance or rejection to the responsible government activity. This forum works best when debate can be conducted at the semi-annual coordination group meetings. Therefore, it

appears that the current six-month revision cycle is probably fixed.

Another question which must be raised is whether a printed version of the handbook should still be issued. Powerful arguments can be made for continuing to issue a printed handbook. Many users may not have access to a network. Reference copies need to be saved for later use. In fact, a large majority of current MIL-HDBK-5 users insisted in a recent survey that a printed version of the handbook should always be available.

With the existence of both printed and computerized versions, a question of which version is "Official" arises. This question may not be an issue if, as discussed above, the current six-month change and revision cycle is maintained. Changes to the network could be programmed simultaneously with the issuance of new printed handbooks.

IV. SUMMARY OF REQUIREMENTS:

From the discussion above, it is clear that in order to accomplish any form of a computerized version of MIL-HDBK-5, certain requirements must be in place. These requirements should be met regardless of whether a computer version of the handbook is desired simply for publication purposes, or whether it is desired as a reference database:

1. Text and tables should be included together in the same word-processed document. The word-processor should be a desktop publishing package which is compatible with the SGML markup language. The exact requirements should be confirmed with the Naval Publications Center in face-to-face meetings.

2. Illustrations should be drawn on a CAD system and saved in IGES format. This should again be confirmed with the Navy.

3. Graphs should be digitized in such a manner that the x-y coordinates can be displayed by pointing with a mouse. Best-fit curves as well as the individual data points should be displayed if they are available. Graphs should be saved in IGES format.

4. It would be most desirable to incorporate the IGES illustrations and graphs in the correct sequence in the

file. In other words, ideally, the computer file should be able to be scrolled through as if the pages of the handbook were being turned. This may or may not be immediately possible; if it is not possible, it should not stand in the way of a computerization effort. An interim publication version could be created which would serve as an electronic filing cabinet. All the text and tables could be in one file, graphs in separate files, and so on. These files could be used by the document custodian to create an original hardcopy manuscript to be mailed to the Naval Publications Center. This would improve the revision process as it stands today and be a useful intermediate step until a fully "Navy-compatible" system can be developed.

5. The questions of what version is "Official," and how the printed handbook can be kept as current as a database version can be solved easily. The database should not be updated until the printed change notices are ready, so both versions would be identical.

6. Even though a database can be updated instantly, the existing review and debate procedures should be maintained to insure the integrity of the data. The semi-annual meetings to approve changes should be maintained.

7. The focus of a developing a computerized MIL-HDBK-5 should be to construct a database which duplicates the

existing handbook. If a broader effort were initiated in which an expert design system was desired, it would unnecessarily divert attention away from the desired purpose of creating a computer version of the existing handbook.

V. WHERE DO WE CURRENTLY STAND?

The requirements listed above seem to be very difficult to meet, but many segments of the integrated approach listed above have been completed under different technical efforts funded by private and federal organizations. Two promising systems under development are worthwhile to discuss.

A. THE MPD NETWORK: The MPD Network consists of several databases tied together through a network server and accessible on-line to subscribers. The various databases include an agricultural database, a petroleum database, and others. In a telephone conversation, the program manager, Gil Kaufman, discussed his work towards developing a materials selection optimization system using MIL-HDBK-5 design allowables. His system would be accessible through the network.

The proposed MPD materials selector is not proposed to reproduce a page of MIL-HDBK-5. It is designed to search an allowables database to select materials which meet certain criteria.

Of special interest, however, is MPD's success in digitizing the MIL-HDBK-5 graphs on computer media. According to Mr. Kaufman, the digitized graphs are true representations of the curves, and x-y coordinates can be defined by the computer. A subcontractor, Sci-Tech Knowledge Systems of Albany, NY, has captured the curves using a custom software package and can display and interpolate data using a separate software program. Mr. Kaufman recommended that Sci-Tech be consulted regarding transfer of the data into IGES format.

In any case, the Sci-Tech digitized graphs should be investigated for possible inclusion in any proposed MIL-HDBK-5 database.

B. ADVANCED MATERIALS DATABASE SYSTEM: PDA Engineering of Costa Mesa, California, has developed a database access system called "Advanced Materials Database System" (AMDBS). A prototype AMDBS tape developed for a VAX computer system was evaluated for this report. Although the available tape had graphics that were not compatible with the VAX system used to evaluate the program, the program worked very well in every other aspect. AMDBS allows the user to select a database from a list of available files, including advanced composite fibers, matrix materials, and MIL-HDBK-5. The user is then asked to scroll through a list of materials in the selected database to choose the material and form of interest, e.g., 7150-T76 aluminum forgings less than two inches thick. Tabulated allowables data are then displayed.

According to a report describing the program, curves can also be plotted.

A shortcoming of the PDA program is that no footnotes or cautionary statements were displayed with the data. None of the MIL-HDBK-5 text was displayed, so the database was not a reproduction of the handbook. However, AMDBS was easy to work with and may serve as a good base for further development.

C. SRS TECHNOLOGIES: SRS Technologies of Huntsville, Alabama, was contracted through a US Air Force Small Business Innovative Research (SBIR) effort to develop an interactive database for spacecraft materials. The project has shown little tangible results to date, although the SBIR was funded in September 1984. The concept was to create a database of spacecraft materials which would be accessible to users throughout DOD, NASA, and contractors.

Although the Phase I report of the SBIR presented plans for an integrated database of critical spacecraft materials, the execution of the Phase I plan was not successful to date in Phase II. The database became "contaminated" with very general, poorly-defined manufacturers' data; test methods and other characteristics about the data were not provided. In addition, a wide range of general materials were included in the database (including construction-grade silicone caulks, etc.).

The SRS effort has some lessons learned which may affect the computerization of MIL-HDBK-5:

1. Although the materials to be included in the MIL-HDBK-5 database are well defined by the printed handbook, great care should be taken in the accuracy of the transcribed data. The problems with the SRS effort underscore the importance of including the footnotes and other descriptive comments about the data.

2. Good program management is critical to a project of this magnitude. Any problems or shortcomings should be brought into the open immediately, to insure data integrity and to insure that the database is indeed MIL-HDBK-5 quality.

3. Each step of the program should be documented clearly and completely. That way, if changes in computer hardware are required, or if key personnel depart (as was the case with SRS), the effort can continue.

VI. CRITICAL QUESTIONS WHICH MUST BE ANSWERED:

Before a full program can be initiated to computerize MIL-HDBK-5, several questions must be answered.

First, Naval Publications Center requirements should be clearly defined in face-to-face discussions. This is the most critical step in converting MIL-HDBK-5 to a truly useful computerized format.

It must be determined if a computerized version of the handbook for printing and publishing can be completely compatible with an interactive database. Based on the preliminary information gathered for this report, it appears feasible that if the Navy's guidelines are met for sending a fully computerized document to the Naval Publications Center, then that document may be compatible with a database. If they can be the same, then "Approach #1" (computerize MIL-HDBK-5 for publishing purposes) and "Approach #2" (computerize a MIL-HDBK-5 interactive database) can be combined into one, single effort.

PDA Engineering should be consulted about the compatibility of their data search function of their AMDBS database with common spreadsheet programs. If they can be made compatible, the MIL-HDBK-5 allowables can be stored in spreadsheet files, complete with comments. Those files could be used for two purposes: one,

to print the data tables out or display them on the screen, or two, to be searched for specific allowables data similar to the AMDBS system. It should also be determined if those files can be incorporated into desktop publishing software.

The accuracy of the MIL-HDBK-5 curves digitized for the MPD Network should be checked. In addition, the ability to point to a spot on the curve to obtain x-y coordinates should be confirmed.

The possibility of converting the MPD Network MIL-HDBK-5 curves into IGES format should be investigated. It would be most desirable to save them in standard IGES format to reduce compatibility problems later.

VII. SPECIFIC ACTIONS REQUIRED:

1. Key WRDC/MLSE personnel should visit MPD Network in Columbus, Ohio, to define:

   a. The accuracy of the MPD Network MIL-HDBK-5 curves.

   b. The ability to get x-y coordinates from random points on the curves.

   c. The status and format of the MIL-HDBK-5 database.

2. Sci-Tech Knowledge Systems of Albany, NY, should be visited to determine if the graphs created for MPD Network can be converted to IGES format.

3. *PDA Engineering* should be consulted or visited to determine the format of their database, and to see if spreadsheet-based data can be incorporated into their database.

4. The Naval Publications Center should be visited to get definitive answers on required formats, software, etc., to determine if the same computerized version of MIL-HDBK-5 can serve as a publication aid and as an interactive database.

5. ASTM Committee E49 on Standardized Computer Databases should be contacted to learn of any special requirements or procedures for new databases. It would be best to meet as many new standards as possible.